PROGRAM OF RESEARCH ON THE MANAGEMENT

OF RESEARCH AND DEVELOPMENT

Department of Industrial Engineering and Management Sciences
The Technological Institute
Northwestern University
Evanston, Illinois

FINAL REPORT:

# STUDIES AND ANALYSES OF THE MANAGEMENT OF SCIENTIFIC RESEARCH AND DEVELOPMENT, INCLUDING IMPLEMENTATION AND APPLICATION AT NASA CENTERS

Albert H. Rubenstein
August 1975

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OUTLINE

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## 1. INTRODUCTION

It is difficult to summarize the results of a series of grants such as the ones provided by the University Support Program of NASA to the POMRAD (Program of Research on the Management of Research and Development) at Northwestern University over more than a decade. There have been many different kinds of outputs, including: publications, working papers, reports, research findings, ideas, new and revised theories, new and improved methodologies for conducting research on the Research & Development/Innovation (RD/I) process and, above all, trained people who are continuing to engage in research and/or management practice in the RD/I field.

POMRAD has been an integrated, multi-project program in the RD/I field for over 20 years (its origins were at Columbia University and M.I.T., where the Principal Investigator was on the research staff and faculty, respectively). Selection of projects and sub-program areas (e.g., project selection and resource allocation, information-related behavior of researchers, environmental factors affecting creativity and productivity of research groups, technology transfer) has been guided by the cumulative nature of theory building and verification in the field, particular research opportunities that are continually arising, and the commitments and interests of thesis students, faculty, and other research staff members.

Support for POMRAD has been provided by a wide variety of private and government foundations and agencies, including: NASA, National Institutes of Health, The Ford Foundation, Army Research Office, Department of Defense, Office of Naval Research, many different programs in the National Science Foundation, private companies, and university funds and support for graduate students.

It is, therefore, impossible to point to specific projects or publications or degree candidates and say that they were "produced" exclusively by the NASA grant. On the other hand, the broad, unstructured support provided by NASA has been invaluable in providing the kind of flexibility which a basic research program such as POMRAD's requires to pursue both its research and training objectives (graduate and post-doctoral).

All of the sub-programs in POMRAD's overall program (see section 2) have benefited from the NASA grants and some of them (e.g., Decentralization, Crises, Skills, OR/MS, LINCOTT, Achievements) received their initial impetus and/or their major support from the NASA grant. During the period of the grants, NASA support has constituted from approximately 10 to 30% of POMRAD's total support (more in the earlier years, less in recent years).

The balance of this final report includes some statistics on the output of POMRAD over the period of the grants, in terms of papers, publications, and people; descriptions of the major program areas; and some comments on the "spin-offs" of the association with NASA over the years of the grant continuing up to the present. The actual list of papers, names of doctoral and masters theses, and other details of the program are contained in the periodic reports of POMRAD, which are included as appendices to this final report.

## 2. NATURE OF THE OVERALL PROGRAM AND SPECIFIC PROJECTS UNDERTAKEN

2.1 The primary characteristics of Northwestern's Program of Research on on the Management of Research and Development (PONRAD) have been:

2.1.1 Focus on R and D/Innovation: Our research program is focused specifically upon increasing the understanding of the R&D/Innovation (RD/I) process.

2.1.2 Management Science Setting: The ideas, theories, and techniques of many pertinent fields have been brought to bear on this research area at Northwestern through the diverse training and experience of our faculty and advanced graduate students. These fields include most branches of engineering, physics, economics, operations research, sociology, law, psychology, political science, anthropology, business administration, and industrial management. The location of this research program in the Department of Industrial Engineering and Management Sciences in the engineering school at Northwestern provides a very important environmental asset. Major teaching and research areas of the department are: Operations Research, Information Sciences, Organization Theory, and Systems Design. Students and staff members in the research program participate in all of these areas. The program is an integral part of the Organization Theory area of the Department.

2.1.3. A Basic and Applied Approach: Our program may be described as basic research in the Management Sciences. However, it is also an applied research program with respect to the specific problems of managing research and development and innovation (RD/I). That is, we have selected the specific projects in our program on the basis of their importance in the practice of RD/I management. We believe that this set of problems represents key issues in the field and that increased understanding of them will contribute to significant improvements in the art of RD/I management in all kinds of institutional settings.

2.1.4. An Integrated Approach to the Set of Projects: Our method of operation consists of an integrated approach to the whole set of projects

by our research staff. Many of the specific projects grew out of other ones in our program and there is continual feedback and cooperation between members of the staff. That is, we do not work in isolation on separate projects. Results on one project are continually made available to people working on the others. The principal investigator is directly involved in all of the studies in the program and each of the other program members is directly involved in at least one project and indirectly in others.

2.1.5. Each Project Continuing and Cumulative: Each project in the program is really a sub-program in itself, comprising a number of distinct, but related studies, over a period of years. This has permitted knowledge and research methods to cumulate. Examples are: the Idea Flow study which involved seven theses and dissertations, as well as a number of non-theses staff studies; the Technical Achievements study which has produced, since 1958, three distinct published staff studies; the Project Selection study which has involved six theses and dissertations and several staff studies since 1957; and one of our newer project areas - LINCOTT (Number 8, below,) which has involved over a dozen independent but related theses and dissertations. The methodological emphases on field experiments, "real time" studies, more standardized instruments, and remote data collection continue to grow.

2.1.6. Inputs to Organization Design, Science and Technology Policy, and Management Decision-Making: Our interest and activity in "organization design" has grown rapidly in recent years. The outputs of these design studies and of our research studies are intended as inputs to management decision-making and policy - both for RD/I and for some aspects of science (e.g., especially in the developing countries). In addition, members of the Program work closely with many organizations studying and making science and technology policy. We firmly believe that improved understanding of the RD/I process is urgently needed for the improvement of science and technology policy as well as RD/I management.

2.1.7 Some Trends in POMRAD Staffing and Methodology: An important aspect of the Program's staffing over the past few years has been the phase transition of the graduate student group (primarily Ph.D. candidates) involved in the Program. At its most recent peak, the graduate student group participating in the program numbered approximately 20 (all Ph.D. candidates but 3-4). The modal completion time for our Ph.D. candidates has been 4-5 years and a large percentage of the 20 entered the program within a 2-3 year period in the latter half of the 1960's. Eleven of them completed their work in the period 1969-71 and another 16 finished by September 1975. Although new graduate students become involved in the Program each year, the earlier peak size is not expected to be reached again in the near future. Instead, more emphasis in staffing has been placed, over the past 3-4 years, on the participation by post-doctoral researchers and professionals from other fields who have special skills needed in the Program.

Since 1968, for example, six post-doctoral researchers and a half dozen advanced (all-but-the-dissertation) pre-doctoral researchers from other fields have been directly involved in the Program. In addition, as indicated in the list of personnel in section 3, over 20 faculty members at other universities and members of Research Institutes (all but 2 are alumni of the Program) have participated as consultants

This use of post-doctoral people is expected to continue, although it does not mean that people early in their graduate careers are excluded from participation. The Program of Research on the Management of Research and Development is still considered an integral part of the academic program in Organization Theory at Northwestern and is viewed as an importnat research vehicle in the training of doctoral students. However, there has been an increased recognition of the need for more specialized training and experience in organization theory, field research, and the specifics of the RD/I process before a person can make a significant contribution to the field of research-on-research.

## 2.2 Specific Projects Undertaken

### 1. IDEA FLOW IN RESEARCH AND DEVELOPMENT

Objective: The objective of these studies was to describe and, hopefully, make useful predictions about the way in which technical ideas for new R&D projects are originated, communicated, and disposed of. The overall design included individual organization studies and comparative studies. Field investigations were conducted in a number of companies which varied in size, industry and structure. Among the techniques used were several kinds of questionnaires and interviews, examination of internal documents, and, in several sites, direct observation.

The general research questions focused on the following: 1) the sources of ideas; 2) the criteria used by various organizational levels and functional groups in evaluating ideas; 3) the effects of individual backgrounds on criteria used and behavior with respect to idea origination and transmission; 4) organizational procedures for handling ideas; and, 5) the decision processes at various stages of transmission or disposition of ideas.

Supported By: National Science Foundation and National Aeronautics and Space Administration.

Project Leaders: Albert H. Rubenstein and Jack Siegman

### 2. CONTROL OF RESEARCH AND DEVELOPMENT IN DECENTRALIZED ORGANIZATIONS

Objective: This was a study of the characteristics and behavior of decentralized organizations as they affect the inputs to, capabilities of, and output from R&D. The sample of organizations that has been studied consists of over 200 of the largest industrial companies in the U.S.

Some of the questions which have been addressed in this study involve: the effects of size on organizational structure; alternative means of organizing and coordinating dispersed R&D facilities; criteria for choosing overall R&D strategies by very large organizations; organization planning in large organizations; effects of external environment on organizations (economic,

technical, social); headquarters/field relationships; effects of incentives on managers; and problems of managerial control.

Supported By: National Aeronautics and Space Administration and the McKinsey Foundation.

Project Leader: Michael Radnor.

### 3. STRATEGIES FOR ORGANIZATION AND DIFFUSION OF RESEARCH IN DEVELOPING COUNTRIES

Objective: This project is concerned with the many problems of organizational design and policy that relate to the establishment, maintenance, and effectiveness of an R&D capability in a newly developing country. In addition to the specific foci of individual dissertations by members of the "developing countries" group, the group as a whole has focussed on a number of major issues in this field. Among them are: the different patterns for the establishment of R&D institutes in the over 100 countries in our study population; methods and problems of technology transfer, both indigenous and international; regional cooperation in R&D and the problems and effectiveness of regional research institutes; the relative roles of government and the private sector in establishing and maintaining R&D capabilities; the infrastructure for support of R&D (e.g., intermediaries in attempts to apply or implement the results of government-conducted R&D); and the impacts of national science policy on the conduct of R&D. Models and propositions attempting to explain and predict aspects of the above issues are central to our work in this area, and these are developed from and tested via empirical data gathered in the field in the developing countries.

Supported By: Ford Foundation (through the Council on Intersocietal Studies at Northwestern University, the National Science Foundation (through a series of dissertation grants), and the Army Research Office.

Project Leader: Albert H. Rubenstein.

### 4. R AND D RESPONSES TO CRISES, AND BARRIERS AND INCENTIVES IN THE RD/I PROCESS

Objective: This project concerns the reactions of the firm, in terms of R&D behavior, to contraints, opportunities, and changes in the marketplace, technology, the economy, and other environmental conditions. A sample of firms in each of several relatively clearly defined markets has been studied.

Supported By: National Aeronautics and Space Administration, National Science Foundation.

Project Leaders: Albert H. Rubenstein and Alok K. Chakrabarti

## 5. SOURCES OF R AND D ACHIEVEMENTS IN ELECTRONICS SINCE 1945

Objective: The objective was to attempt to relate the incidence of R&D achievements in electronics to certain characteristics of the organizations reported to have been responsible for them.

Supported By: National Aeronautics and Space Administration.

Project Leader: Dawson E. Brewer.

## 6. THE ACQUISITION AND DEVELOPMENT OF NEW TECHNICAL SKILLS IN RESEARCH AND DEVELOPMENT

Objective: This was an attempt to learn the cost and time necessary for R&D organizations to build new capabilities in technical fields. The concept of "capability" and how it is achieved is the central question under study.

The "skills" required to do R&D are considered to be attributes of people, and a group of people working together in a technical area constitute a "capability." Closely related to the study are the problems of "technical obsolescence" faced by all R&D performing organizations, in particular, those pioneering in many fields. Vulnerability to obsolescence comes from, among other sources, the need to occupy a wide front in many rapidly changing fields and the common difficulty of maintaining strength in depth in all or most of them. A corollary problem is that of retraining or skill retreading where such obsolescence has occurred.

Supported By: National Aeronautics and Space Administration.

Project Leader: Gustave J. Rath.

## 7. INTEGRATION AND UTILIZATION OF MANAGEMENT SCIENCE ACTIVITIES IN ORGANIZATIONS

Objective: The study is concerned with the general process of introduction and adoption of operations research and management science (OR/MS), and

related activities in organizations. The objective is to describe and then, hopefully, to predict the transition of operations research and other management science groups as they become integrated into the organization (if they do). The effects of many internal and external factors are being tested in a series of studies. Questions of implementation and effectiveness are central aspects.

Supported By: National Aeronautics and Space Administration, the Ford Foundation (through Northwestern's Council on Inter-Societal Studies), and Booz, Allen & Hamilton Foundation.

Project Leader: Michael Radnor.

## 8. LINCOTT: LIAISON, INTERFACE, COUPLING AND TECHNOLOGY TRANSFER BETWEEN PHASES OF RESEARCH, DEVELOPMENT AND APPLICATION

Objective: This series of studies is aimed at increasing our understanding of the important factors involved in the exchange of ideas and information between individuals and groups who are attempting to work together, exchange information, or transfer technology in the complex research-to-applications process. Emphasis is on inter-organizational transfers of ideas and information.

Supported By: National Aeronautics and Space Administration, National Science Foundation, and Army Research Office.

Project Leader: Albert H. Rubenstein.

## 9. THE INFORMATION-RELATED BEHAVIOR OF RESEARCHERS

Objective: Many different information-seeking behaviors are available to scientists and engineers. The behavior selected by a given individual depends upon (among other factors) his own personal style and the content of his work. His organization, or the larger environment may constrain his style or may determine what specific behavior he follows. Information-seeking style is visualized as a stable behavior pattern, for mature researchers, developed early in the professional lifetime of an individual. The information-seeking styles prevalent in a group may be one determinant of R&D group effectiveness. This series of studies is focused on improving our understanding of the nature of "information style" - both constrained and "unconstrained" and examining its sources and consequences.

Supported By: National Library of Medicine, Public Health Service; National Aeronautics and Space Admin.; National Science Foundation; and Office of Naval Research.

Project Leaders: Robert D. O'Keefe and Charles W. N. Thompson.

## 10. PROJECT SELECTION AND RESOURCE ALLOCATION IN R AND D

Objective: To describe currently used R and D project-selection processes and to formulate models that might be used to improve them. The long-run objectives are "real-time" information and computation systems to aid the R and D manager and other managers in project selection and review.

Supported By: The Army Research Office (Army Materiel Command), National Aeronautics and Space Administration, and Office of Naval Research

Project Leader: William E. Souder.

## 11. KEY RESEARCHABLE PROBLEM AREAS IN R AND D MANAGEMENT

The formal phase of this study was completed in 1966 (document 66/1), supported by the Office of Naval Research. However, in the terms of our own project No. 10, the processes of"project selection and resource allocation" go on continuously in our Program of Research on the Management of Research and Development. In contrast to an industrial or government research organization, however, the initiation, continuation, level of effort, and termination of individual sub-projects (e.g., theses and dissertations) as well as the entering of new fields within the R&D management area depends to a very large extent on individual choice by students and staff members. There are a number of aspects of the "research-on-research" field which are not in our program, which need attention and on which other groups and individual investigators are working. The level of effort in over-all "research-on-research" seems to have held up in the U.S. and to have grown in Europe in the past ten years (see the two most recent directories of research-on-research - documents 71/40 and 68/20, listed in our previous program reports, under project No. 14). This is despite the cut-back in funds by some federal agencies which were active in this field, notably ONR, ARO, NASA and the Department of Defense. Many key researchable areas are reflected in the two directories mentioned above and, we hope, by our own project portfolio.

## 12. ENVIRONMENTAL AND MANAGEMENT FACTORS INFLUENCING THE PERFORMANCE OF RESEARCH AND DEVELOPMENT GROUPS

Objective: The original focus of this project was the series of studies associated with project HINDSIGHT, in particular the phase which dealt with the environment in which producers of "R&D Events" (e.g., pieces of information, inventions, ideas) worked at the time that the events occurred. Other aspects of the R&D group environment have been and are being explored in other contexts. In particular, the work of Kegan, Hill, and Lipson reflect this expanded set of interests in the general topic of R&D group behavior, environmental constraints, and performance. In addition, some work by Ogliastri and others relate to the particular aspects of group training and preparation for working together. Although no major program thrust is currently anticipated on this overall topic (separate, that is, from the "organizational climate" studies done by Barth under project No. 8), there is always the possibility that one or more members of the program will catch fire in this area and develop a series of additional studies.

One spin-off from our interest in this "group environment" area has been our work with the Industrial Research Institute on attempting to design a series of field experiments aimed at improving the creativity and productivity of R&D groups (see document 70/71).

## 13. METHODOLOGY OF RESEARCH ON RESEARCH

Objective: To continually examine and attempt to improve our current methods of field research, theory building and testing, model construction and measurement, and to develop new ones for specific and general use in our overall program. All the projects and sub-programs in our program have a secondary objective of improving our methodology.

## 14. OTHER RELATED ACTIVITIES

A. The Transactions on Engineering Management of the Institute of Electrical and Electronics Engineers: IEEE Transactions on Engineering Management continues to be edited at Northwestern. It remains the only U.S. professional society journal devoted exclusively to the management of Research, Development, and Engineering (RD&E). Recently, however, two new European journals have appeared

on the scene, with very similar foci. Competition for readers and manuscripts is friendly, however, and the principal investigator of the Program of Research on the Management of Research and Development is on the advisory board of both of them. The two new journals are: R & D Management, edited at the University of Manchester and Research Policy, edited at the University of Sussex. These two groups are the largest "research-on-research" activities in England.

In response to reader comments, the Transactions is attempting to obtain more articles from managers of R, D, and E who have useful and interesting things to report, as a supplement to the heavily academic content of many of the issues. This balance between the presentation of new theory and research results on the one hand and the presentation of immediately useful management techniques and insightful "wisdom" articles on the other remains a perennial problem for all journals with a mixed specialist and general readership.

B. The College on Research and Development (COLRAD) of The Institute of Management Science (TIMS): Two main activities occupied the Northwestern group in relation to COLRAD in recent years - preparing the third (European) edition of the Directory of Research-on-Research and participating in and organizing sessions of COLRAD at the national and international meetings of The Institute of Management Science. Three such sessions were organized by Rubenstein and Souder, and several other members of the program participated in them and other sessions.

C. Short Courses and Seminars: An annual Seminar on Organization of Research and Development, designed for R&D managers in the Chicago area has been conducted since 1960 and occasional short courses and seminars are conducted by PORRAD members in the U.S. and abroad.

D. Advisory Relations with other Related Groups: In addition to their individual consulting work with private companies in the field of R&D management, members of the group participated in advisory and consulting assignments with these governmental and not-for-profit organizations recently: Office of the Science Director, United Nations; Office of the Foreign Secretary, National Academy of Sciences; Organization of American States; The Center

for Studies of Research and Development in Paris; The Scandinavian Research Council; The Industrial Research Institute; The National Aeronautics and Space Administration (Langley Field Center); The Small Business Administration; Illinois Institute of Technology; The Organization for European Cooperation and Development; Institute for Defense Analysis; U.S. Bureau of Mines, the International Institute for Applied Systems Analysis; UNESCO; Council of Scientific and Industrial Research (India); Korean Institute of Science and Technology.

As usual, many talks, informal papers, and lectures were given by members of the Program over the years. Where a manuscript copy is available, it has been included in listings under the appropriate project number. In many cases, however, they were "slide talks" and no manuscripts are available.

## 3. PEOPLE ASSOCIATED WITH THE PROGRAM (1964-75)

During the past ten years over 20 Ph.D. degrees have been awarded to Organizational Theory students in the Technological Institute (the engineering school) at Northwestern. They have all worked in the Program of Research on the Management of Research and Development (POMRAD). In addition, another 10 Ph.D.'s who have completed their work in Organizational Behavior in the School of Management at Northwestern have also worked closely with, and in several cases been financially supported by POMRAD. Of this group of Ph.D.s, most are currently located in universities in the U.S. and Canada (some are in industry and other activities) and have continued to work with us in our various studies of the RD/I process.

This is a new generation of academic researchers. Most entered the program with earlier training in Science or Engineering and have received intensive training in behavioral science, systems, and economics. In addition, from the beginning of their graduate work, they have been involved in proposition-based field research of the RD/I process. Many of them have continued to work in areas related to their own dissertations as well as working with POMRAD on other projects in our portfolio. Those who are located in universities with doctoral programs in organization theory/organizational behavior have begun to produce their own generations of doctoral students, trained in field study methodology and working on aspects of the Rd/I process. Since the "stayers" in this field of research-on-research or the RD/I process have been only a small percentage of those who do dissertations in related subjects,* we have endeavored to encourage this network of graduates to remain in the field and to continue contributing to our knowledge about the RD/I process. We have used a number of means of doing this where funding and university rules have permitted. Several have been employed as post-doctoral researchrs or research engineers after their dissertation work has been completed. Others have been employed by POMRAD for a summer or an academic-year quarter or have been given a sub-contract to compensate their own university for their academic year time. Almost all have been employed as consultants on our various projects.

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*A. H. Rubenstein, "Research-on-Research: The State of the Art in 1968," Research Management, Vol. XI, No. 5, September 1968.

In this way, we accomplish two major objectives: 1) we have the advantage of well-trained, experienced researchers in this difficult field, who share our methodological viewpoints and can readily fit into our various project teams and 2) we help them to continue to be active in the RD/I process until they can become established on their own as full professionals with their own research programs and graduate students. This provides a whole new generation of researchers in this area who are not afraid to get out into the field and study the RD/I process in vivo.

## PERSONNEL ASSOCIATED WITH THE PROGRAM, 1964-75

### Principal Investigator

Albert H. Rubenstein, Professor of Industrial Engineering and Management Sciences

### Other Northwestern University Faculty

Arthur P. Hurter, Professor of Industrial Engineering and Management Science

Isabel Juan, Visiting Assistant Professor of Psychology

Michael Radnor, Professor of Organizational Behavior, Graduate School of Management

Gustave J. Rath, Professor of Industrial Engineering and Management Science

William E. Souder, Visiting Assistant Professor of Industrial Engineering and Management Sciences (now at University of Pittsburgh)

Charles W. N. Thompson, Associate Professor of Industrial Engineering and Management Sciences

### Consulting Faculty at Other Universities and Research Institutes*

Norman R. Baker, Professor and Chairman of Industrial Engineering; University of Cincinnati

Richard T. Barth, Associate Professor, Faculty of Commerce and Business Administration, University of British Columbia

Alden S. Bean, National Science Foundation, Washington, D.C.

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* All but six of these were originally associated with POMRAD as Research Assistants, graduate students, Research Engineers or Post-Doctoral Fellows.

Victor A. Berlin, Boston College, Boston (now at National Bureau of Stds.)

Alok K. Chakrabarti, Assistant Professor of Marketing, DePaul University

Jerome Cohen, Professor of Psychology, Northwestern Medical School

William A. Davig, Food Research Institute, Campinas, Brazil

Carlos Davila, University of the Andes, Bogota

Charles F. Douds, Associate Professor of Managment, DePaul University

John E. Ettlie, Assistant Professor, University of Illinois, Chicago

Gerson A. Greenburg, University of California, San Diego, Medical School

William A. Hetzner, Illinois Institute of Technology Research Institute, Chicago

Stephen C. Hill, Professor, Dept. of Sociology, University of New South Wales, Australia

Allen D. Jedlicka, University of Northern Iowa, Cedar Falls, Iowa

Bokook Jeon, Korea Institute of Science and Technology, Seoul, Korea

Ronald O. Johnston, University of Manchester, Manchester, England

Takeshi Kawase, Faculty of Engineering, Administrative Engineering Dept., Keio University, Tokyo

Daniel L. Kegan, Hampshire College, Amherst

David W. Kennard, Professor of Psychiatry, The Albany Medical College of Union University

John A. Kernaghan, Assistant Professor, University of Indiana

Jinjoo Lee, Assistant Professor, Korea Advanced Institute of Science

Howard R. Lipson, Montreal, Quebec

P. Michael Maher, Associate Professor, The University of Alberta

Colin Mick, Post Doctoral Fellow, Stanford University

William C. Moor, Associate Professor, Arizona State University

Evelyn A. Moore, North Carolina State University

Enrique Ogliastri, University of the Andes, Bogota

Robert D. O'Keefe, Assistant Professor, DePaul University

Theodore W. Schlie, Denver Research Institute, University of Denver

C. Richard Shumway, North Carolina State, Raleigh

Jaime Silva, University of the Andes, Bogota

Richard W. Trueswell, Professor, University of Massachusetts

James M. Utterback, Massachusetts Institute of Technology, Cambridge

Ellis R. Wayne, Academic Administrator, California College of Medicine, University of California at Irvine

Earl C. Young, Associate Professor, Illinois Institute of Technology

H. Clifton Young, Associate Professor, The University of Alberta

Gerald Zaltman, Professor, University of Pittsburgh

Other Research Assistants, Research Engineers, Post-Doctoral Fellows, Pre-Doctoral Fellows, Trainees, and Other Associated Graduate Students

Michael S. Bergman
David M. Birr
Eliezer Geisler
Richard Herman
Ronald Hughes
Nickolas S. Kaskovich
Kenneth Kirsch
Robert E. Large
John P. Miller
Ed Rifkin
Robert Rifkin
Ralph E. Rockwell
Henry Tockman
Atul Wad
Poking Woo

Other Staff Members

Marilyn Adams
Charlene Brown
Susie Y. Brown
Martha Douds
Jean Gagen
Sue Growney
Cynthia Huffman
Lynda Kuykendall
Ruth Solingen
Kirstin Synnestvedt
Ann B. Woelflein

## 4. WORKING PAPERS, PUBLICATIONS AND THESES

Figures 1 and 2 indicate the Program output during the period of NASA support.

FIGURE 1

Working Papers, Reports, and Publications Produced by POMRAD Staff in the Period 1964 - 75

| Year | Number |
|---|---|
| 1964 | 30 |
| 1965 | 40 |
| 1966 | 51 |
| 1967 | 63 |
| 1968 | 51 |
| 1969 | 62 |
| 1970 | 82 |
| 1971 | 102 |
| 1972 | 111 |
| 1973 | 134 |
| 1974 | 123 |

FIGURE 2

Ph.D. Dissertations and Masters Theses Completed in POMRAD 1964 - 75

| Year | M.S. | Ph.D. |
|---|---|---|
| 1964 | 4 | 2 |
| 1965 | 3 | 0 |
| 1966 | 4 | 1 |
| 1967 | 0 | 3 |
| 1968 | 0 | 1 |
| 1969 | 2 | 3 |
| 1970 | 1 | 4 |
| 1971 | 2 | 1 |
| 1972 | 0 | 6 |
| 1973 | 0 | 4 |
| 1974 | 0 | 3 |
| 1975 | 0 | 3 |
| | 16 | 31 |

## 5. SOME COMMENTS ON THE IMPACT OF THE PROGRAM

It would be satisfying to be able to say that the research conducted by POMRAD over the years of NASA support resulted in the "solving" of some of the important general problems in RD/I management. This, of course, is not the case. Most of the problem areas we have undertaken to investigate - e.g., project selection and evaluation and resource allocation; effects of organizational structure; information-related behavior of researchers; response to external factors; technology transfer - are complex and perennial. The best that we and other researchers can hope for in this field is improved understanding of the way these sub-processes of RD/I work and some clues as to how designers and managers of RD/I activities and organizations can improve their operations. Evidence of the direct application of research results in this field is hard to come by. This is due to: the nature of the diffusion process; the combination of our results with much other information, insights and experience by decision-makers; and the unfortunate kind of secrecy that restricts the sharing of successful problem solving with others. Despite this, however, we have received much gratifying feedback over the years from managers in NASA, industry, and other organizations who have incorporated some of our research results and methods of analysis in their own decision-making, organizational design, and operation of various phases of the RD/I process. Much more direct feedback has been received from fellow researchers in the U.S. and abroad, including in-house analysts within operating RD/I organizations. The great demand for our papers and reports, the invitations to conferences, the many visitors (some for days and some for months or years), and the wide spread citation of our works in the literature and in thesis work indicates that the program has had great impact on the conduct of research in this field.

Much of the credit for this diffusion of our work can be attributed to not only the amount of funding received from NASA (although the annual NASA budgets were fairly modest - averaging $50-60,000 in the peak years), but especially the flexibility of funding, which is described in the introduction. The travel and publication money had a major effect on our ability to communicate our research results and methodological

approach to research in this field. In addition, the ability to provide partial support for visitors from other research institutes and to follow up promising leads and lines of research quickly have been most helpful. In summary, we believe that the kind of support NASA provided to POMRAD has been a major factor in our success in both research and training of professional researchers in this important and complex field of RD/I management.